APEC 2020
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The Film Cap. Tech. For DC Link

法拉电子
FARATRONIC

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201912

APEC Booth 1156

PSMA

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Agenda:

- Capacity introduction and main customers
- The film capacitors technology for DC link
- Reliability test and performance
- Roadmap and Development strategy

Capacity (DC-Link caps for automotive)

- Factory location : HQ
- Current Capacity : 45 kpcs/month
- Production Layout: Station

- Factory : New DC-Link caps factory
- Current Capacity : 80 kpcs /month
  - Line 1: 20 kpcs / month
  - Line 2: 30kpcs / month
  - Line 3: 30kpcs / month
- Planning : Line 4: 30kpcs / month
- Production Layout: Automation Line (Connection from Soldering Process -- Packing Process)

DC- Link Capacitors' Selling Q'ty in year 2019: 600kpcs

Marketing Segment for Automotive Market

- 30% European Market
- 70% Domestic Market

Main Customer

BOSCH Invented for life

Continental

ZF

Valeo 法雷奥

Zollner

UAES

NIO

BYD

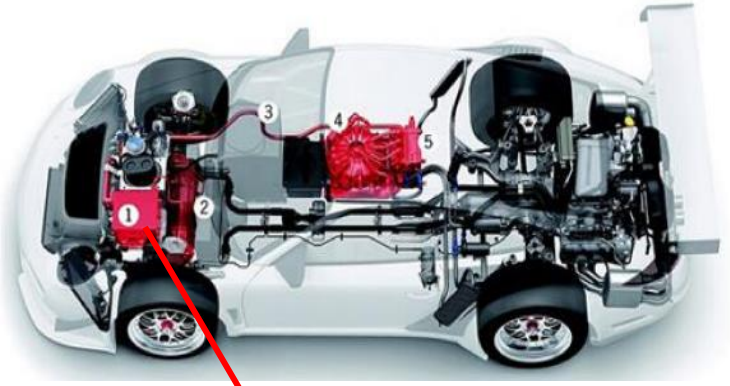
电驱动 EDRIVE

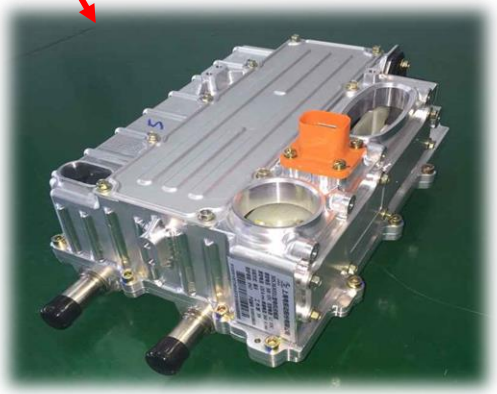
Inovance

PSMA

➢ The film capacitors technology for DC link

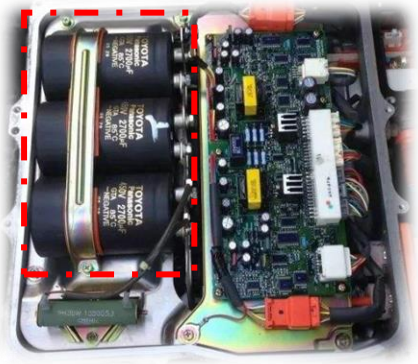
- DC link capacitor becomes one of the key components in the inverter of EV/HEV.





Inverter

Old solution: Electrolytic capacitors

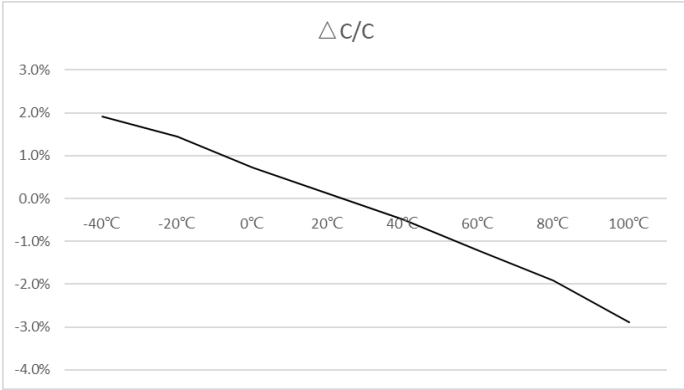


Current solution: Film capacitor

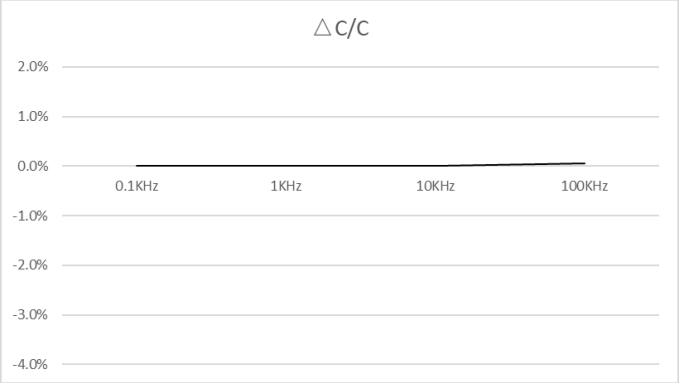
- Properties of polypropylene film compare with electrolytic capacitor

➢ Capacitance is stable in operation temperature and frequency

PP-film capacitor

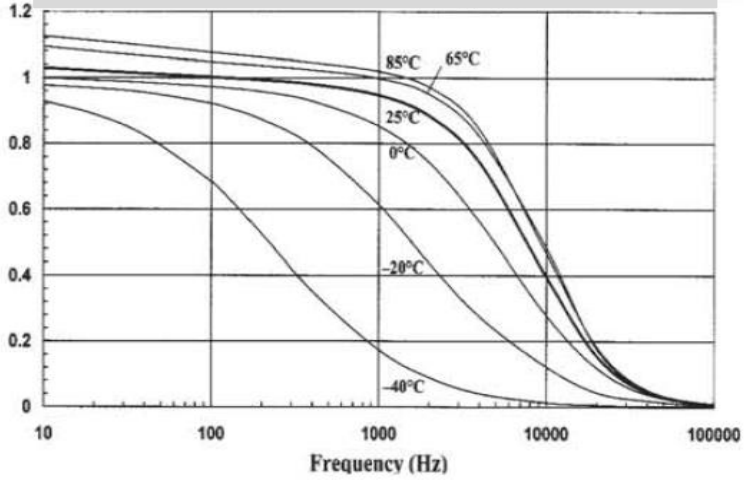


Capacitance drift≤5% (-40℃～100 ℃)



Capacitance is stable (100Hz～100 KHz)

Aluminum electrolytic capacitor



➢ High voltage proof ability
➢ Low ESR, high ripple current handling ability
➢ Low ESL
➢ Long lifetime
➢ Customize design

- Properties of polypropylene film compare with other dielectric film materials

Advantage:

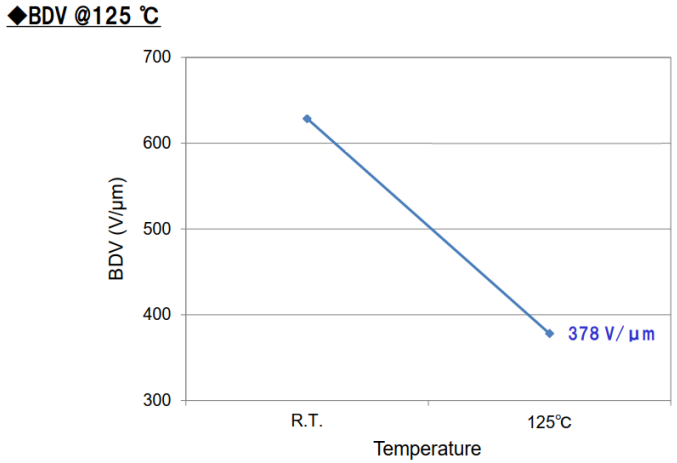
- Low losses;
- Small volume;
- High voltage proof ability;
- Excellent self-healing property
- Good stability;
- Low cost

Disadvantage:

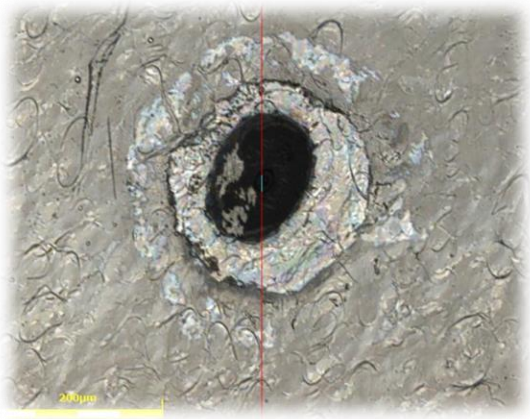
- Operation temperature lower than 115℃

Properties \ Dielectric material	PP	PET	PEN	PPS	PTFE
High temp.	No so good	General	Excellent	Excellent	Excellent
Low losses	Excellent	No so good	No so good	General	Excellent
Volume	General	General	General	No so good	Bad
High-voltage	Excellent	General	General	Bad	General
Stability	General	No so good	General	General	Excellent
Price	Excellent	General	Bad	Bad	Bad

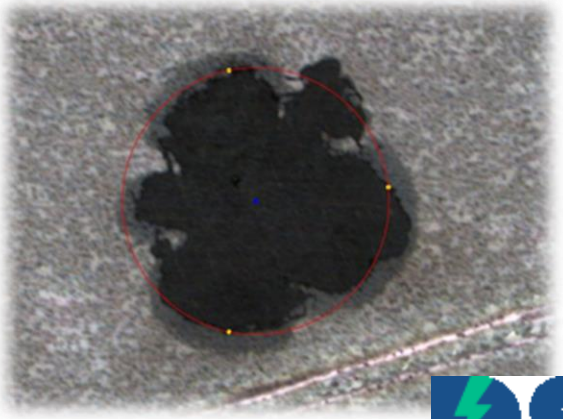
Break down voltage of PP film



Good Self-healing point

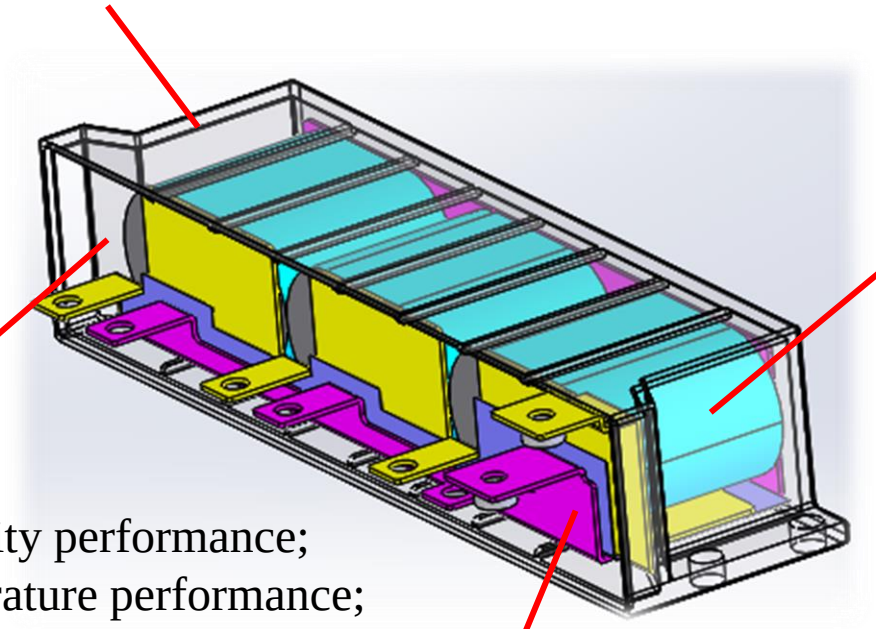


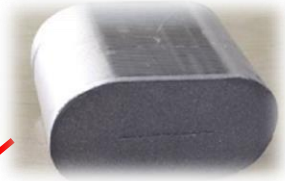
Bad Self-healing point



- Typical structure and features

Housing:
Excellent humidity and mechanical performance





Capacitor element:
Low ESL & ESR;
Special segmented film design;
Heavy-edge technology;
Wave-cutting technology

Epoxy:
Excellent humidity performance;
Excellent temperature performance;

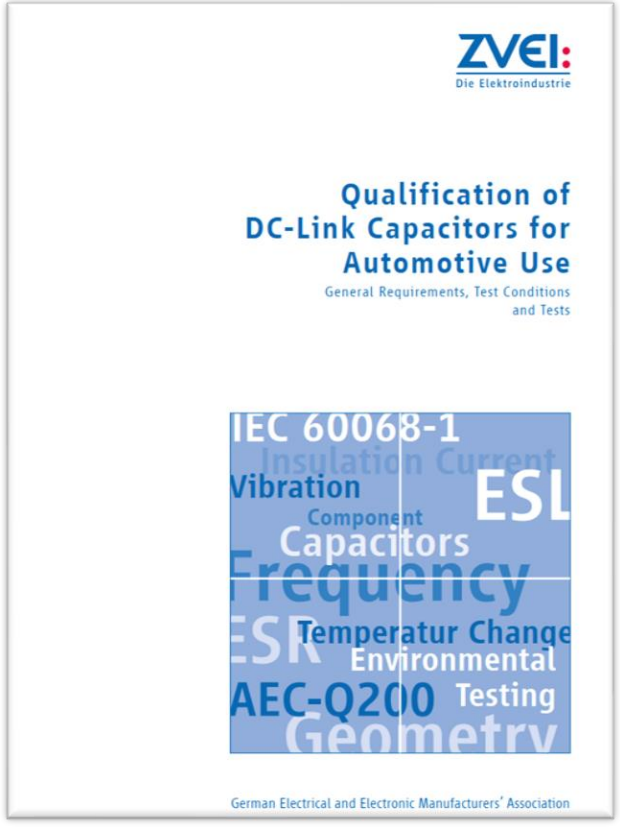
Busbar:
Low ESL & ESR;
Easy assembly

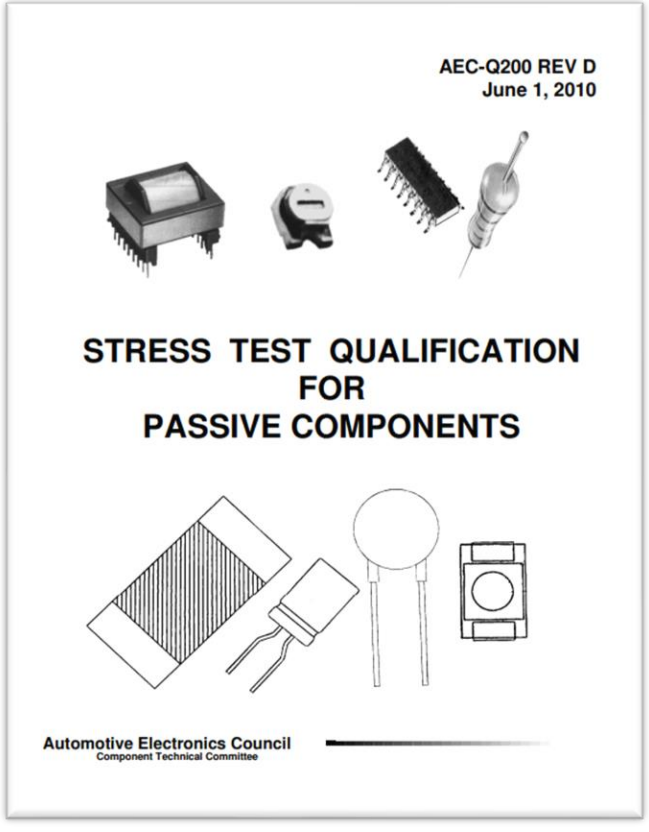
➢ Reliability test and performance

- Test condition reference

1) AECQ 200D

2) ZVEI-Qualification_KFZ-DC-Link-Capacitors





AEC-Q200 REV D
June 1, 2010

Automotive Electronics Council
Component Technical Committee

TABLE 4 - TABLE OF METHODS REFERENCED FILM CAPACITORS

Stress	NO.	Reference	Additional Requirements
Pre- and Post-Stress Electrical Test	1	User Spec.	Test is performed except as specified in the applicable stress reference and the additional requirements in Table 4.
High Temperature Exposure (Storage)	3	MIL-STD-202 Method 108	1000 hrs. at rated operating temperature (e.g. 85°C part can be stored for 1000 hrs at 85C. Same applies for 100°C & 125°C parts.). Unpowered. Measurement at 24±4 hours after test conclusion.
Temperature Cycling	4	JESD22 Method JA-104	1000 cycles (-55°C to 85°C) Note: If 100°C or 125°C part the 1000 cycles will be at that temperature rating. Measurement at 24±4 hours after test conclusion. 30min maximum dwell time at each temperature extreme. 1 min. maximum transition time.
Moisture Resistance	6	MIL-STD-202 Method 106	t = 24 hours/cycle. Note: Steps 7a & 7b not required. Unpowered. Measurement at 24±4 hours after test conclusion.
Biased Humidity	7	MIL-STD-202 Method 103	1000 hours 40°C/93%RH. Rated Voltage. Measurement at 24±4 hours after test conclusion.
Operational Life	8	MIL-STD-202 Method 108	1000 hours T_A=85°C, Note: Condition D (1000 hrs) If 100°C or 125°C the 1000 hrs. will be at that temperature. Metallized Film: 125% of rated voltage at 85°C. 100% of rated voltage above 85°C. Measurement at 24±4 hours after test conclusion.
External Visual	9	MIL-STD-883 Method 2009	Inspect device construction, marking and workmanship. Electrical Test not required.
Physical Dimension	10	JESD22 Method JB-100	Verify physical dimensions to the applicable device specification. Note: User(s) and Suppliers spec. Electrical Test not required.
Terminal Strength (Leaded)	11	MIL-STD-202 Method 211	Test leaded device lead integrity only. Conditions: A (2.27 kg), C (227 g), E (1.45 kg-mm)
Resistance to Solvents	12	MIL-STD-202 Method 215	Note: Also aqueous wash chemical - OKEM clean or equivalent. Do not use banned solvents
Mechanical Shock	13	MIL-STD-202 Method 213	Figure 1 of Method 213. Condition C
Vibration	14	MIL-STD-202 Method 204	5g's for 20 minutes, 12 cycles each of 3 orientations Use 8"X5" PCB, .031" thick. 7 secure points on one 8" side and 2 secure points at corners of opposite sides. Parts mounted within 2" from any secure point. Test from 10-2000 Hz.

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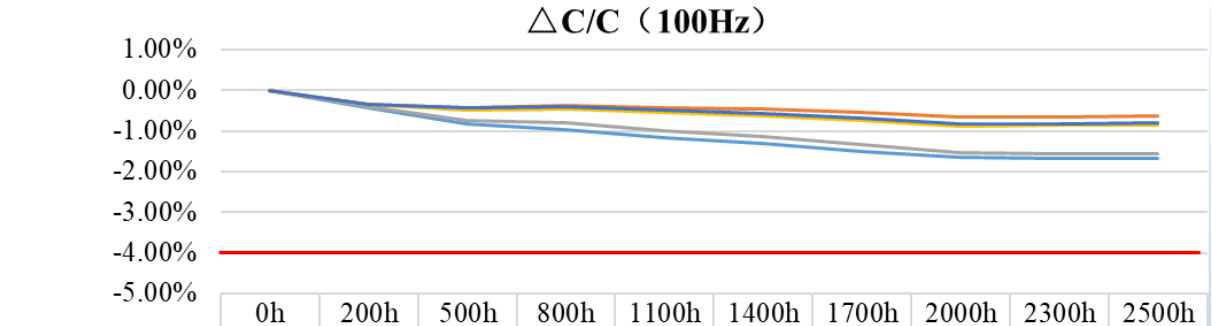
- Main reliability test and performance

Operational life test

Test condition: Rated voltage, Maximum operation temperature, 2500 hours
Failure mode: Capacitance loss & ESR increasing
Causes : Material aging, oxidation of metal, plastic parts performance at maximum temp., internal connection.

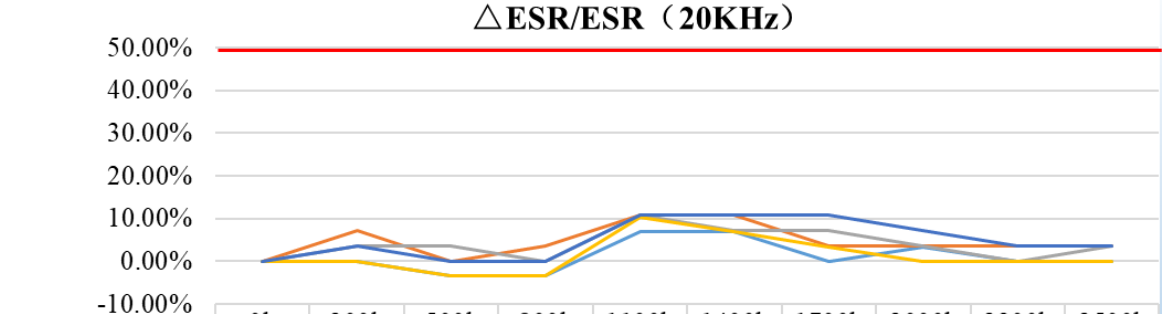
Typical test case:

Capacitance loss



	0h	200h	500h	800h	1100h	1400h	1700h	2000h	2300h	2500h
2Y00990821	0	-0.44%	-0.83%	-0.96%	-1.15%	-1.32%	-1.51%	-1.64%	-1.68%	-1.67%
2Y00990820	0	-0.34%	-0.43%	-0.38%	-0.42%	-0.45%	-0.55%	-0.67%	-0.66%	-0.62%
2Y00990828	0	-0.41%	-0.73%	-0.80%	-0.99%	-1.14%	-1.35%	-1.53%	-1.55%	-1.55%
2Y00990823	0	-0.35%	-0.48%	-0.47%	-0.55%	-0.62%	-0.74%	-0.88%	-0.87%	-0.85%
2Y00990817	0	-0.36%	-0.43%	-0.42%	-0.50%	-0.57%	-0.68%	-0.81%	-0.82%	-0.81%

ESR increasing



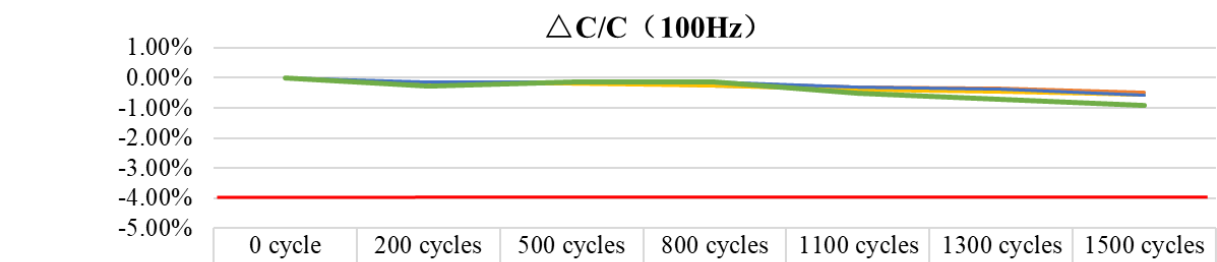
	0h	200h	500h	800h	1100h	1400h	1700h	2000h	2300h	2500h
2Y00990821	0	0.00%	-3.45%	-3.45%	6.90%	6.90%	0.00%	3.45%	0.00%	0.00%
2Y00990820	0	7.14%	0.00%	3.57%	10.71%	10.71%	3.57%	3.57%	3.57%	3.57%
2Y00990828	0	3.57%	3.57%	0.00%	10.71%	7.14%	7.14%	3.57%	0.00%	3.57%
2Y00990823	0	0.00%	-3.45%	-3.45%	10.34%	6.90%	3.45%	0.00%	0.00%	0.00%
2Y00990817	0	3.57%	0.00%	0.00%	10.71%	10.71%	10.71%	7.14%	3.57%	3.57%

Temperature cycling test

Test condition: 60min./60min. TH to TL, rapid change, T＜1min.
Failure mode: Crack, Capacitance loss, ESR increasing
Causes : Material aging, oxidation of metal, internal connection, internal mechanical stress variation.

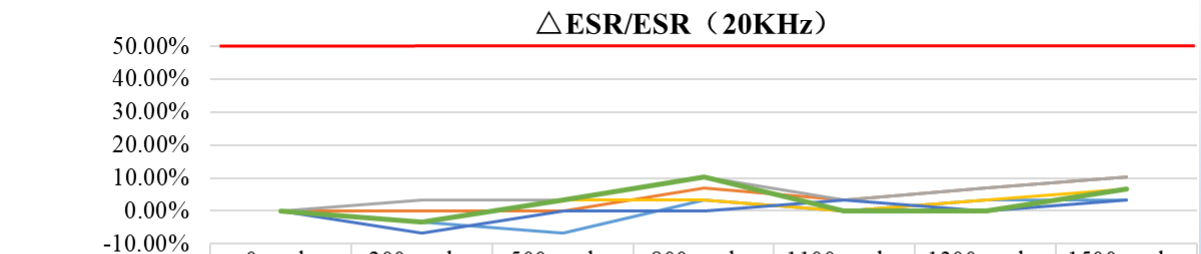
Typical test case:

Capacitance loss



	0 cycle	200 cycles	500 cycles	800 cycles	1100 cycles	1300 cycles	1500 cycles
2Y00990826	0	-0.18%	-0.18%	-0.16%	-0.31%	-0.40%	-0.49%
2Y00991200	0	-0.19%	-0.12%	-0.18%	-0.29%	-0.35%	-0.46%
2Y00991210	0	-0.24%	-0.13%	-0.26%	-0.37%	-0.38%	-0.57%
2Y00991203	0	-0.21%	-0.19%	-0.27%	-0.40%	-0.47%	-0.56%
2Y00991209	0	-0.15%	-0.15%	-0.14%	-0.30%	-0.36%	-0.59%
2Y00991205	0	-0.26%	-0.12%	-0.14%	-0.52%	-0.72%	-0.90%

ESR increasing



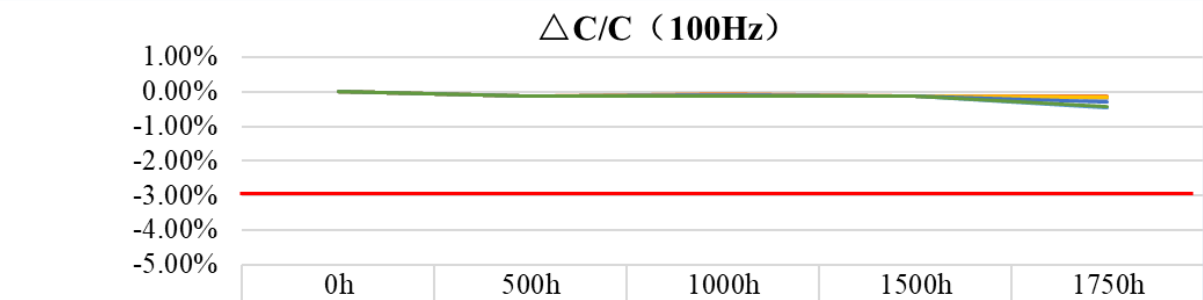
	0 cycle	200 cycles	500 cycles	800 cycles	1100 cycles	1300 cycles	1500 cycles
2Y00990826	0	-3.33%	-6.67%	3.33%	0.00%	3.33%	3.33%
2Y00991200	0	0.00%	0.00%	6.90%	3.45%	6.90%	10.34%
2Y00991210	0	3.45%	3.45%	10.34%	3.45%	6.90%	10.34%
2Y00991203	0	-3.33%	3.33%	3.33%	0.00%	3.33%	6.67%
2Y00991209	0	-6.67%	0.00%	0.00%	3.33%	0.00%	3.33%
2Y00991205	0	-3.33%	3.45%	10.34%	0.00%	0.00%	6.67%

Bias humidity test

Test condition: Rated voltage, 65℃, 93% RH, 1750 hours
Failure mode: Capacitance loss, ESR increasing
Causes: Humidity resistance ability of material, oxidation of metal, internal connection

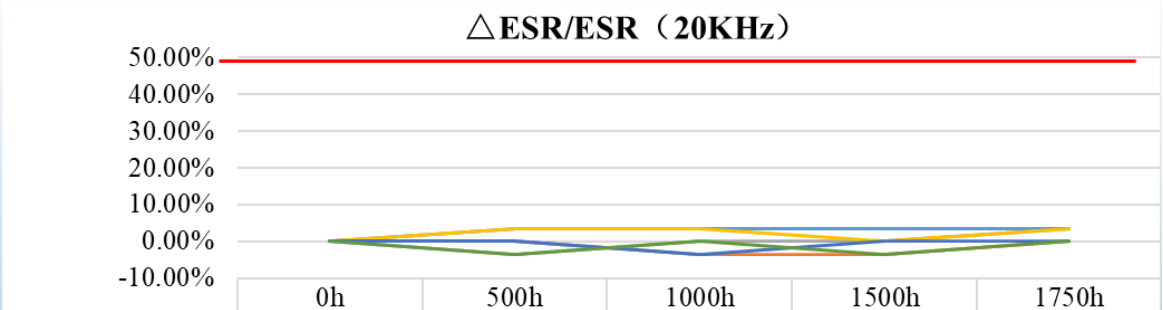
Typical test case:

Capacitance loss



	0h	500h	1000h	1500h	1750h
2Y00991196	0	-0.14%	-0.12%	-0.14%	-0.48%
2Y00991206	0	-0.12%	-0.04%	-0.12%	-0.11%
2Y00991199	0	-0.11%	-0.11%	-0.12%	-0.21%
2Y00991202	0	-0.12%	-0.11%	-0.12%	-0.15%
2Y00991211	0	-0.13%	-0.11%	-0.12%	-0.30%
2Y00991214	0	-0.12%	-0.11%	-0.13%	-0.43%

ESR increasing



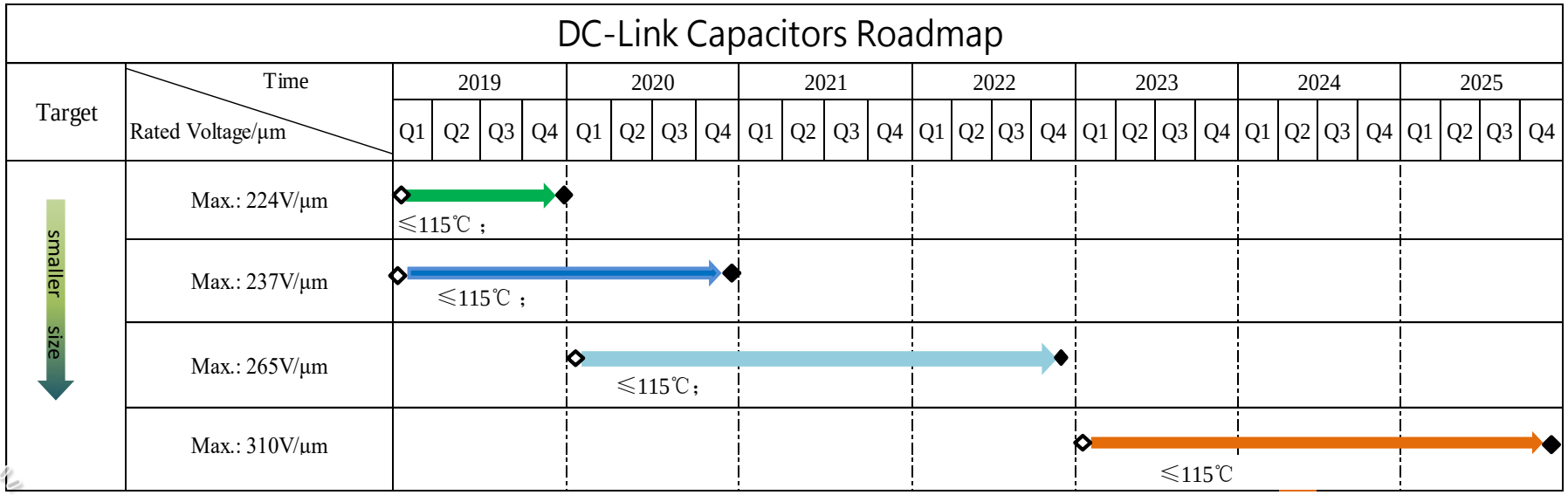
	0h	500h	1000h	1500h	1750h
2Y00991196	0	3.57%	3.57%	3.57%	3.57%
2Y00991206	0	0.00%	-3.45%	-3.45%	0.00%
2Y00991199	0	-3.45%	0.00%	0.00%	3.45%
2Y00991202	0	3.57%	3.57%	0.00%	3.57%
2Y00991211	0	0.00%	-3.45%	0.00%	0.00%
2Y00991214	0	-3.45%	0.00%	-3.45%	0.00%

➢ Roadmap and Development strategy

- According to the market requirements, development tendency of DC link film capacitor should be:

Smaller volume → Higher temp. → Light weight → Higher ripple current handling → Higher frequency application

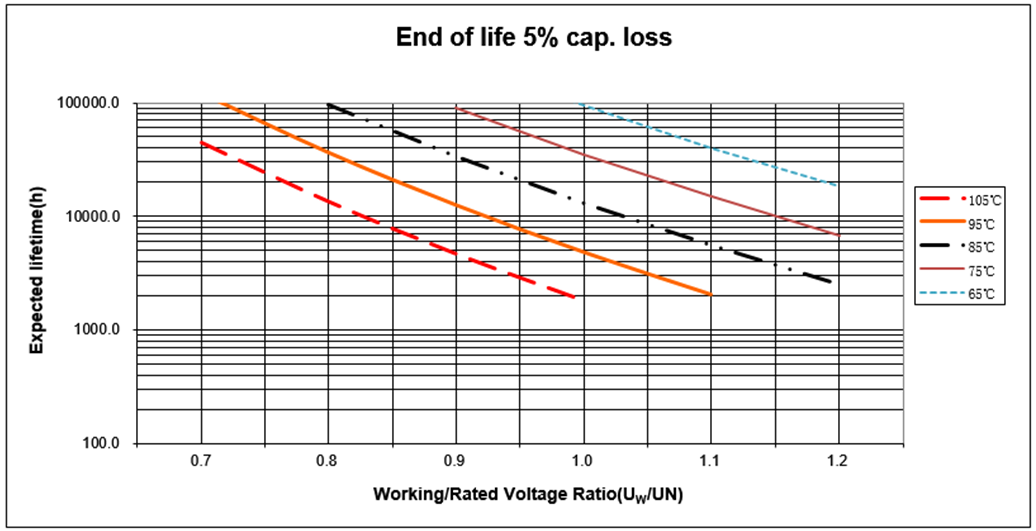
- Roadmap for PP film DC Link capacitor



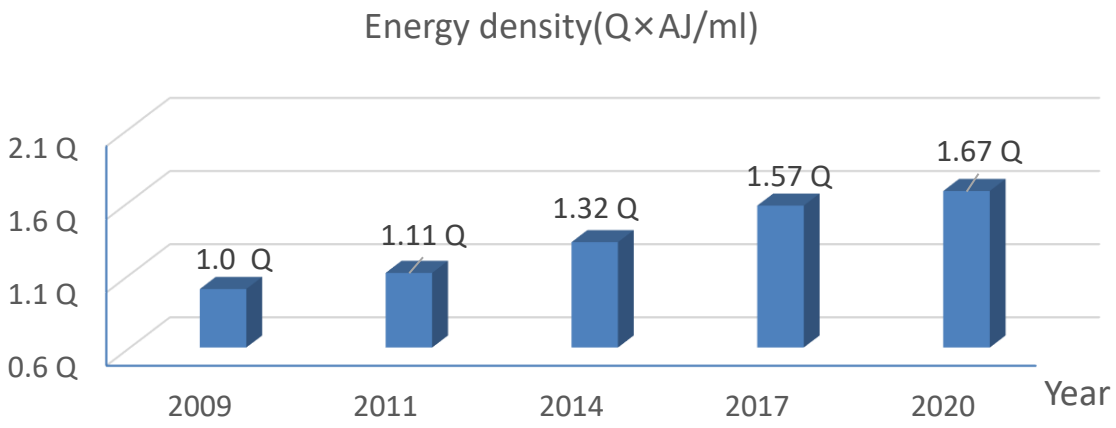
Target:
Smaller volume and light weight!

- Development works for PP film capacitor
  - PP film optimization(work with raw material supplier)
  - Metallization process optimization
  - Capacitor manufacture process optimization
  - Lifetime study for design optimization

Typical lifetime curves:

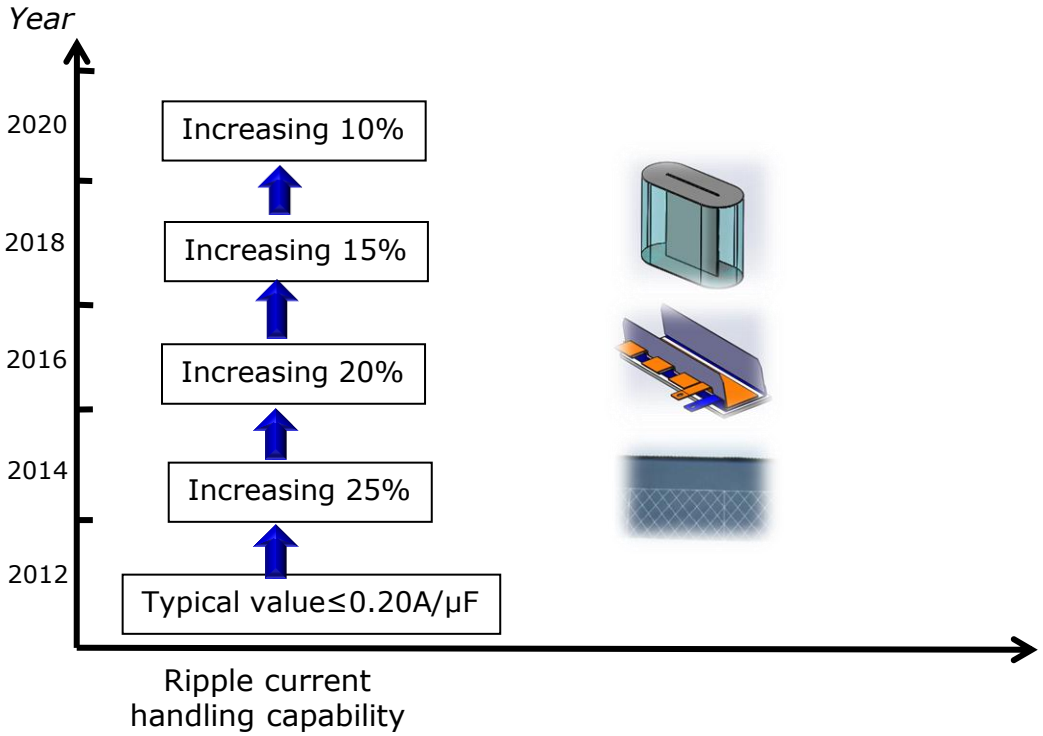


Energy density change of Faratronic's film capacitor

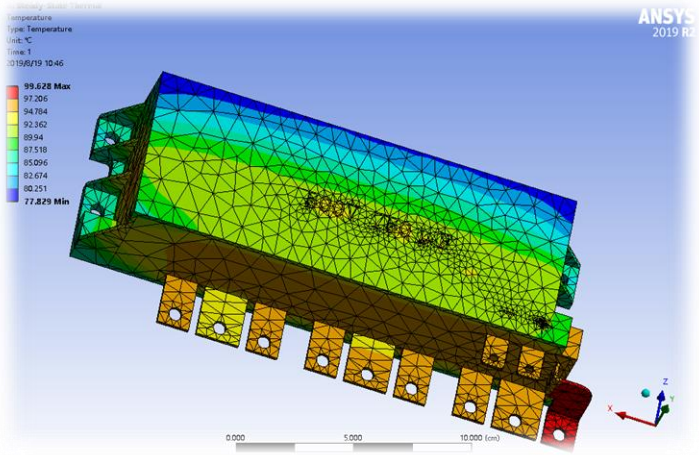


A	B	C	D	E
450V-2.9 μm	450V-2.7 μm	450V-2.4μm	500V-2.4μm	475V-2.2 μm

- Ripple current handling ability improvement



- Increase max. operation temperature from 105℃ to 115 ℃
- ESR improvement: Metallization layer design optimize; Narrow metallization film design.
- Thermal conductivity improvement of potting material
- Special cooling structure design
- Optimize thermal performance via simulation result



- Lower ESL for higher frequency application

Typical value:

~2015: 10~15nH

2016~2020: 5~10nH

2021~: ≤5nH

- ➢ Lamination busbar optimization
- ➢ Low ESL terminal design
- ➢ Low ESL internal connection design

ESR curves@ different terminal design

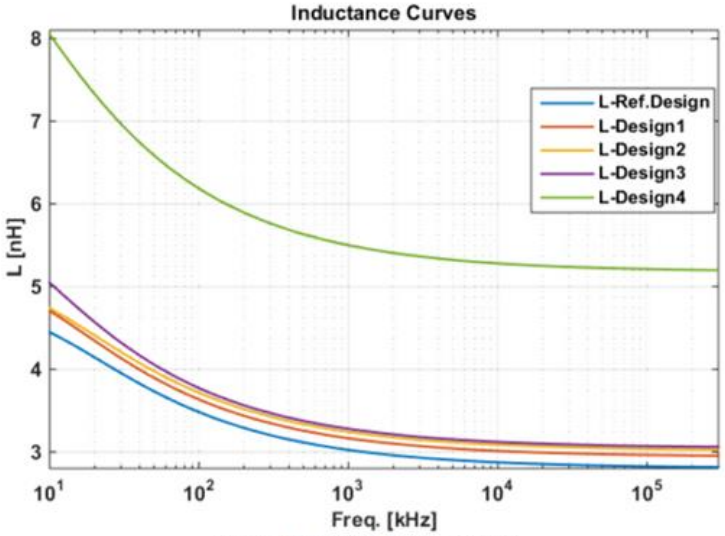
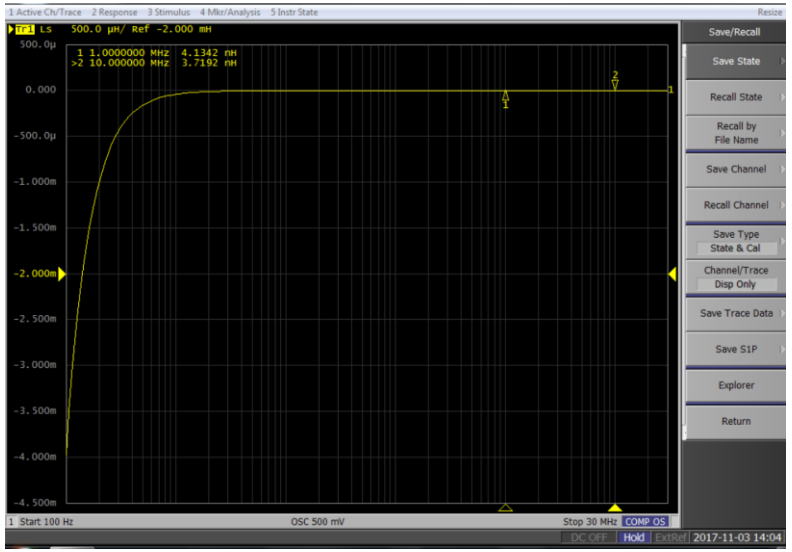


Figure 2-1: Inductance Curves

ESL measurement



- Roadmap for high temperature DC Link film capacitor

Materials	Time / Hotspot temp.	2018				2019				2020				2021				2022				2023			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
PEN-HV	125 ℃	Samples				Pilot products																			
Other H.T. materials	140 ℃	Film application researching								Samples								Pilot products							

Target:
Higher temperature!

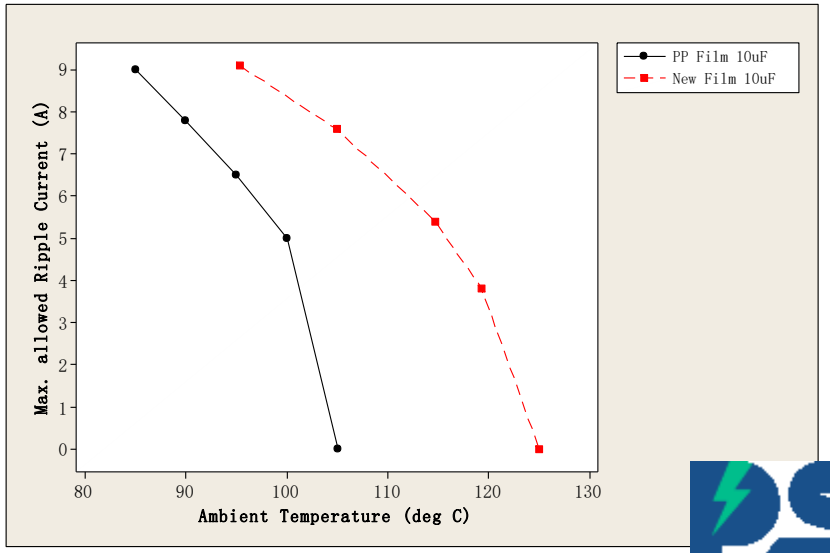
Sample introduction:

DC-Link Film capacitor for EV/HEV power electronics **at 125℃**.

Properties:

- High heat resistance**[continuously 125 ℃, short time 150 ℃]**.
- Higher allowable ripple current under higher temperature environment than PP film capacitor(**105 ℃**).
- High frequency range.

Ripple current handling capability



Thank You

Faratronic, your trusty partner

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